NUTRIENT BALANCES IN AGRICULTURE

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Abstract

The concept of farm gate balance is well known from the environmental literature, and it focuses on nutrients (nitrate) getting into the farming unit within purchased inputs and those leaving it in sold products (or in other ways). This method is not suitable in every case to show the nutrient load for the environment of agricultural companies that is the reason why unit level internal nutrient balances are applied to express the level of nutrient pollution on the environment. With the help of precise information about the nutrient management the firm can decrease the nutrient loss of the production processes. With the survey of the nutrient flows within the farm we determine the nutrient load of the pollution sources. On the basis of the results of the unit level internal balances we make recommendations for the most appropriate environmental policy instrument to reduce the nutrient pollution.

Key words: external nitrogen balance, internal nitrogen balance

INTRODUCTION

Environmental problems caused by agriculture have appeared from the early 1970s and from this time they have become more and more intensive. "From the early 1990s onwards, European Union environmental policies and measures have increasingly affected agricultural production and started to overrule national environmental policies and measures" ([7]). Nowadays one of the most important environmental policy instruments in the agriculture of the European Union is the Nitrate Directive (91/676/EC), which was agreed upon by all member states in 1991. The objective of the Nitrate Directive is to decrease agricultural water pollution induced by nitrate and prevent further nitrate pollution. The Nitrate Directive limits not only the amount of animal manure that could be applied to agricultural land but the period of its application, too. Countries where intensive animal production with small agricultural land is characteristic were affected disadvantageously by the regulation. In these countries the direct implementation of the manure application restriction could have contributed to a serious cutback in animal livestock ([10]). In this way the Mineral Accounting System (MINAS) was introduced in the Netherlands, which was completed by the manure application restriction later. The MINAS is a farm gate balance well known from the environmental literature that focuses on nutrients getting into the farming unit within purchased inputs and those leaving it in sold products (or in other ways) (see [2], [5], [6], [8], [14]). The positive difference of the farm gate balance is the nutrient surplus and the negative difference is the nutrient deficit both expressed in nutrient kg. The nutrient surplus can be considered as nutrient loss, which can be harmful for the environment. The main aims of the farm gate balance are to enhance the efficiency of nutrient management of the farms and to ensure compliance with the Nitrate Directive. In the cause of reducing nutrient loss a stimulating system was initiated in the same time with MINAS. On the basis of the stimulating system a certain amount of nutrient expressed in kg was determined, which is not considered to pollute the environment. But farms have to pay levies when nutrient surpluses exceed these target surpluses (arable land: 100 kg for nitrogen nutrient per ha, grassland: 180 kg for nitrogen nutrient per ha) ([8], [10]). The farm gate balance, however, could not become general in the European Union. The main criticism against the method is that the farm gate balance is based on the "black box" principle comparing the amounts of nutrients entering the farm from the input markets to those leaving it towards the output markets, considering the difference between the two as nutrient loss ([15]). Farm gate balance does not take into account nutrient flows within the farm. In this way this method could not manage the stock changes. Due to the unsold products at the end of the farming year the difference in the nutrient contents of the purchased and sold materials can be higher than in the former year. The major part of the difference is not a loss, nor is it stored in the soil, but is contained in the unsold stocks of the farm ([15]). In Hungary the agricultural farms generally have unsold stock at the end of the farming year. If they adopt the concept of farm gate balance for determining the nutrient loss of the production progress the amount of balance of the purchased and sold nutrients would distort the information about the nutrient management of the farm. To avoid this problem it needs to identify the nutrient flows within the farm, in order to clarify the "black box" principle. Instead of farm gate balance it is worth setting up the internal nutrient balance at farm level comparing the annual yields and the annual amounts of nutrient utilized in the farm. The farm level internal nutrient balance shows more precise information about the nutrient management of farms than the farm gate balance ([14], [15]).

However, further problems could arise from putting this method in practice. If the agricultural firm has several different units (crop production and animal husbandry enterprises) and the production processes of these units are integrated with each other, the internal nutrient balance at farm level could lead to false information about the nutrient management of the farm.

The internal nutrient balance at farm level could show an efficient nutrient management as a result while nutrient processes may have happened in opposite directions in the units of the farm. Nutrient deficit in the crop production unit means the utilization of nutrients having been spread in the former years. The nutrient surplus in the animal husbandry means nutrient accumulation in the environment. The sum of the positive (nutrient surplus) and negative (nutrient deficit) nutrient differences could obscure the inefficiency of the farm nutrient management. To solve this problem the internal nutrient balances could be set up at unit level, and in this way nutrient flows between the units could also be surveyed.

MATERIALS AND METHODS

The objective of our study was to set up farm and unit level nutrient balances for nitrogen nutrients for the 2001 – 2003 farming years. We examined whether MINAS is suitable or not to reduce the nutrient load for the environment, and determined the nutrient load of the units of the farm.

The main agricultural activity of the farm is animal husbandry, which is served by the crop unit. The major part of the crop yields is consumed by animals and the smaller part of the crop yield is sold. It has a cattle enterprise specialized to dairy farming of nearly 700 animals, for which the fodder is produced mainly by the company's own arable land (above 1000 hectares) and by the silage coming from its 300 hectares meadow and pasture area. In the first place we dealt with internal nutrient balances, which could whiten the "black box" principle; internal nutrient balances were divided into 3 separate balances (the crop, fodder mixer and animal husbandry units. Differences in the approaches may be found, some of the researchers (see e.g. [8]) do not count with all possible components (e.g. the nitrogen fixation by legumes, atmospheric deposition), while others (as e.g. [9], [13]) include these components in their calculations. In our analyses we made an effort to take into account only precise objective data found in the analytic records of inventories of the farm. But once we made an exception for the amount of ammonia in nitrogen kg volatilized from the production processes, which was taken into account by the data of the literature ([3]).

The primary data sources for farm and unit level nutrient balances are usually available within the traditional accounting system, namely the quantities given in the analytic records of inventories. The respective nutrient contents of the various plant and animal materials and products (e.g. crop yields, fodders, fertilizers, manures, livestock, animal products, etc.) are attached to the quantities of these materials given by the analytic records according to the form of stock change. The unit nutrient contents may be found in the relevant literature ([1], [4], [11], [12]) and in research results by Katalin Sárdi. Then the following values were computed ([15]):

- The external nutrient balance (ENB, farm gate balance) is the difference of nutrients entering the farm (or unit) with purchased materials (P) and leaving it with sold stock (S) including perished animals (ENB = P - S).

- The internal nutrient balance (INB) is the difference of nutrients utilized by the production processes (U) and the nutrients leaving the farm (or unit) with the yields or outputs (Y) (INB = U - Y).
- The stock change (SC) is the difference of nutrients of closing balance and opening balance of the inventories, and is the same as the difference of external and internal nutrient balances (SC = ENB – INB).

RESULTS AND DISCUSSION

First of all the nitrogen flows of the production processes within the farm were surveyed to clarify the "black box" principle (Table 1). Secondly, we set up the farm level external (farm gate balance) and internal nutrient balances (Table 2) for 2001 – 2003 farming years and the latter one was developed to unit level (Table 3). Table 1 represents the components of external and internal balances at farm level for 2001 and Table 2 contains only the balances for 2001, 2002 and 2003.

Table 1

Components of external and internal nitrogen balance at farm level 2001 (kg)

Components	Purchase (P)	Yield (Y)		Utilization (U)		Sales (S)	SC
		C	F + A	C	F + A		
Animal, animal products	0	0	20005	0	733	19604	-332
Manure	0	0	4936	2811	0	1049	1075
Fodder	35902	0	47417	0	89828	352	-6861
Cash crops	0	156227	0	276	69058	69764	17128
Seed	1176	0	0	1138	0	44	-7
Fertilizer	225788	0	0	184058	0	41730	0
Total	**262866**	**156227**	**72358**	**188283**	**159619**	**132543**	**11003**

C: Crop unit F: Fodder mixer unit A: Animal husbandry unit

Table 2

External and internal nitrogen balances at farm level 2001 – 2003 (kg)

Components	2001		2002		2003	
	ENB	INB	ENB	INB	ENB	INB
Animal, animal products	-19604	-19271	-17146	-20914	-21922	-21008
Manure	-1049	-2125	-692	785	-927	-8560
Fodder	35550	42411	39971	35585	36650	49658
Cash crops	-69764	-86892	-34473	-32455	-24341	-3013
Seed	1131	1138	371	371	368	364
Fertilizer	184058	184058	158357	134897	122062	140762
Total	**130322**	**119319**	**146388**	**118269**	**111890**	**158203**

Table 2 shows that there is some difference between the results of the external and internal nutrient balances at farm level. The differences confirm our former statement that in the presence of the stock changes at an agricultural firm it is better to set up the internal nutrient balance instead of external nutrient balance (farm gate balance) at farm level to get information about the nutrient management. According to the results of internal nutrient balances at farm level we can establish that the efficiency of the nutrient utilization changed for the worse in 2003. The results cannot give suitable information for the management to reduce surpluses and to improve the efficiency of nutrient management.

The reason is that the internal nutrient balance at farm level cannot explore which unit or production process needs to get intervention to stop the inefficiency of nutrient utilization. In favour of supporting management it is important to know which unit causes significant nutrient loads for the environment. For this reason, in the following analyses we dealt only with setting up internal nutrient balances at unit level.

Table 3

Internal nitrogen nutrient balances at unit level 2001 – 2003 (kg)

Inputs				Outputs			
Components	**2001**	**2002**	**2003**	**Components**	**2001**	**2002**	**2003**
I. Nitrogen nutrient inputs				**I. Nitrogen nutrient outputs**			
I/1. Inputs to crop production				**I/1. Outputs from crop production**			
Fertilizer	184058	134897	140762	Grain	79440	50868	36360
Seed	1415	1070	1356	Maize for silage	28489	30839	18528
Manure	2811	7968	2084	Hay, straw	48298	34223	21277
I/1. Total	**188284**	**143935**	**144202**	**I/1. Total**	**156227**	**115930**	**76165**
				Balance (CINB)	**32057**	**28005**	**68037**
I/2. Inputs to fodder mixer				**I/2. Outputs from fodder mixer**			
Maize for silage	26843	27634	17592	Silage	25786	26454	17029
Grain	12863	12283	15178	Fodder	21631	35975	45952
Industry inputs	9348	26061	32528				
I/2. Total	**49054**	**65978**	**65298**	**I/2. Total**	**47417**	**62429**	**62981**
				Balance (FINB)	**1637**	**3549**	**2317**
I/3. Inputs to animal husbandry				**I/31. Outputs from animal husbandry**			
Fodder	49540	49684	52033	Meat	3286	3799	2913
Hay	29351	42858	39391	Milk	16719	17890	18779
Silage	30940	22269	28077	Manure	4936	7183	10645
Milk	733	776	684	**I/32. Non-market outputs from animal husbandry**			
				Ammonia	57612	60448	59923
I/3. Total	**110564**	**115587**	**120185**	**I/3. Total**	**82553**	**89320**	**92260**
				Balance (AINB)	**28011**	**26267**	**27925**

Table 3 was completed for a new factor, is the ammonia volatilized from the production processes expressed in nitrogen kg. The reason to count with ammonia is that one of the aims of the Nitrate Directive is to reduce the nitrogen surplus gone to the soil. In this way nutrient balances should not contain the amount of nitrogen which is volatilized into the air as ammonia. In our analyses in farm level internal nutrient balance we did not take into account the amount of ammonia. Disregarding ammonia we could compare the information content of the external nutrient balance with the internal nutrient balance at farm level.

Table 3 shows the results of the unit level internal nutrient balances. We could establish that each unit of the farm contributed to the nitrogen loss. The detailed amounts could explain the increased nitrogen surplus in 2003 (compared to the former years). The decrease of the efficiency of utilized nutrient could be connected to the crop enterprise; the main reason of the decrease of efficiency was the extremely dry weather. However, there is nitrogen nutrient loss gone to the soil in the animal husbandry enterprise, too. The inefficiency of utilized nitrogen nutrient probably derived from the lack of suitable manure disposal. To identify the nutrient inefficiency of the production processes at unit level is the first step for the management to solve the nutrient management problems.

If the Mineral Accounting System (farm gate balance, ENB) were set up in the case of the farm it would not stimulate the management to reduce the nutrient losses of the units.

Table 4

Results of the examination of nitrogen surplus taxation

N	Components	Arable	Grassland	Total	ENB	INB
1.	Levy free surplus kg/ha	100	180			
Total area of the farm (ha)						
2.	Years 2001.	1349	220	1569		
3.	Years 2002.	1029	228	1257		
4.	Years 2003.	1041	309	1350		
Total of levy free surplus (kg)						
5.	Years 2001.	134900	39600	174500	130322	119319
6.	Years 2002.	102900	41040	143940	146388	118269
7.	Years 2003.	104100	55620	159720	111890	158203

The nutrient amount of levy free surpluses defined by MINAS exceeds or is nearly equal to the results of the external nutrient balance (farm gate balance) at farm level (Table 4). The high amounts of levy free surpluses could hide the nutrient load for the environment and whenever the nutrient surpluses exceed the target amount for the farm, it does not influence significantly the fiscal policy of the farm.

CONCLUSIONS

On the basis of our examination we can establish that it is worth setting up the unit level internal nutrient balances instead of farm level internal and external (farm gate balance) nutrient balances to determine the efficiency of the nutrient utilization (nutrient management) of the farm. The results of the nutrient balances at farm level could not provide appropriate (well-detailed) information for the management about the nutrient management of the production processes when there is both nutrient surplus and nutrient deficit in the various units of the farm. The contribution of the units to the nutrient surpluses or deficits varies one by one. In this way different environmental policy instruments are needed to reduce the inefficiency of utilized nutrients and the nutrient load for the environment. In the analysed case study the nitrogen nutrient surpluses in the crop unit are higher than in the animal husbandry and fodder mixer ones. On the other hand the nutrient load of the crop enterprise is lower than the others. The reason is that the nutrient surpluses in the crop enterprise are spread over the lands (approximately 30 – 60 kg nitrogen surplus per ha) so these amounts cannot be harmful for the environment. The inefficiency of the nutrient utilization in the animal husbandry enterprise could be hazardous for the environment. These nutrient surpluses probably derived from the unfavourable manure disposal system could be found in restricted area. In this way they contribute to the nitrate pollution of groundwater and the eutrophication of surface water. However, in the case of the assessed farm the amount of nitrogen nutrient loss does not take financial consequences because the amounts do not exceed the levy-free surpluses defined by MINAS.

With the help of precise and controlled information about the nutrient management the firm can improve the efficiency of utilized nutrient and decrease the nutrient loss. The results and the controlled data of the unit level internal balances can help to select the most appropriate environmental policy instrument to reduce the pollution. To eliminate the nutrient load of the animal husbandry enterprise for the environment it needs to internalize this externality by fulfilling the regulations of Nitrate Directive. The regulation contributes to improve the manure disposal by initiating the construction of manure storage facilities.

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